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Hard- and soft-tissue profiles of the midface region in patients with skeletal Class III malocclusion using cone-beam computed tomography multiplanar-reconstructed image analysis

Bomi Kim[a]
Hyung-Chul Lee[a]
Seong-Hun Kim[a]
Yongil Kim[a]
Woosung Son[a]
Seong Sik Kim[a,b,c]

[a]Department of Orthodontics, Pusan National University Dental Hospital, Yangsan, Korea
[b]Dental Research Institute, Pusan National University Dental Hospital, Yangsan, Korea
[c]Institute of Translational Dental Sciences, Pusan National University, Busan, Korea

Objective: This study examined cone-beam computed tomography (CBCT)-derived multiplanar-reconstructed (MPR) cross-sections to clarify the salient characteristics of patients with skeletal class III malocclusion with midface deficiency (MD). **Methods:** The horizontal and sagittal plane intersection points were identified for middle-third facial analysis in 40 patients in the MD or normal (N) groups. MPR images acquired parallel to each horizontal plane were used for length and angular measurements. **Results:** A comparison of the MD and N groups revealed significant differences in the zygoma prominence among female patients. The convex zygomatic area in the N group was larger than that in the MD group, and the inferior part of the midface in the N group was smaller than that in the MD group for both male and female patients. A significant difference was observed in the concave middle maxillary area among male patients. **Conclusions:** This study was conducted to demonstrate the difference between MD and normal face through MPR images derived from CBCT. Male patients in the MD group had a more flattened face than did those in the N group. Female patients in the MD group showed a concave-shaped lower section of the zygoma, which tended to have more severe MD. These findings indicate that orthognathic surgery to improve skeletal discrepancy requires different approaches in male and female patients.
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Key words: Cone-beam computed tomography, Multiplanar-reconstructed image, Class III malocclusion, Midface deficiency

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Corresponding author: Seong Sik Kim.
Professor, Department of Orthodontics, Dental Research Institute, Institute of Translational Dental Sciences, Pusan National University Dental Hospital, 20 Geumo-ro, Mulgeum-eup, Yangsan 50612, Korea.
Tel +82-55-360-5162 **e-mail** softid@pusan.ac.kr

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INTRODUCTION

Orthognathic surgery is used when achieving proper functional occlusion in the oral and maxillofacial regions with growth control or camouflage treatment is difficult.[1] Class III malocclusion, characterized by maxillary retrusion, mandibular protrusion, or their combination,[2] is considered one of the most complex and difficult orthodontic problems to diagnose and treat. The prevalence of this type of malocclusion is higher in Asian populations (as high as 12%) than in American populations (5%).

Accurate facial analysis is a crucial aspect of successful surgical orthodontic treatment.[3] Many researchers have conducted cephalometric dentoskeletal analyses of skeletal class III deformities.[4-9] However, these studies have focused primarily on the lower facial region, including the nose, upper lip, lower lip, and chin. Research interest in midface analysis has been relatively low. Zide et al.[10] reported that the nasion, orbitale, A point, and other anatomical landmarks on lateral cephalometric plain radiographs represented midface deficiency (MD). Jung et al.[11] analyzed these characteristics in Korean subjects. Singh et al.[12] chose seven points (the subspinale, anterior nasal spine, midpalatal point, rhinion, posterior nasal spine, prosthion, and pterygoid point) on the maxilla as reference points, and analyzed the lengths and angles as expressions of MD. However, the studies by Jung et al.[11] and Singh et al.[12] had limitations when performing the exact measurements of MD because of the many overlying structures in the lateral cephalometric radiographs. To investigate soft-tissue morphology, Nocini et al.[13] suggested a gridplan analysis of the middle-third facial promontories. However, this approach ignores the relationships among the skeletal and soft-tissue characteristics of the midface.

Three-dimensional (3D) dentofacial analysis incorporating cone-beam computed tomography (CBCT) has recently been introduced.[12-16] CBCT images provide accurate, detailed information that could be used to diagnose dentofacial deformities and in treatment planning. Most 3D-CBCT image studies have been restricted to determining mandibular prognathism or facial asymmetry. However, in the present study, CBCT-derived multiplanar-reconstructed (MPR) cross-sections were examined to clarify the characteristics of patients with skeletal class III malocclusion and MD.

MATERIALS AND METHODS

This retrospective study included 40 patients who visited our facility between 2014 and 2015. The sample included 10 male and 10 female patients diagnosed with mandibular prognathism in the MD group, and 10 male and 10 female patients in a normal (N) group. The ages of the patients ranged from 17 to 35 years. The inclusion criteria for the N group were as follows: SNA of approximately 82°, skeletal class I relationship, and no facial asymmetry. The inclusion criteria for the MD group were as follows: SNA ≤ 78°, a soft-tissue profile with the zygoma and ala of the nose located behind the line passing through the eyeball parallel to the natural head position on lateral facial photographs (Figure 1A),

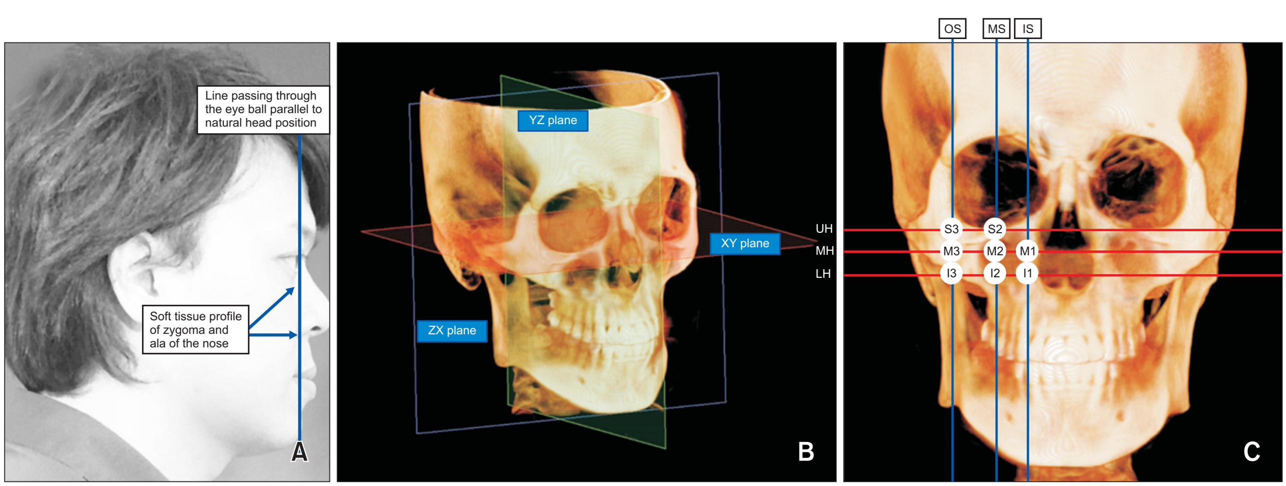

Figure 1. Inclusion criteria for the midface deficiency group. **A**, Soft-tissue profile with the zygoma and ala of the nose located behind the line passing through the eyeball parallel to the natural head position. **B**, Reference planes: XY plane, the horizontal reference plane; YZ plane, the sagittal reference plane; and ZX plane, the coronal reference plane. **C**, Planes parallel to each reference plane: UH, MH, LH, OS, MS, and IS. Intersecting points between the horizontal and sagittal planes were identified for middle-third facial analysis and included the S2, S3, M1, M2, M3, I1, I2, and I3.

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and a mandibular menton point deviation of < 4 mm. The study was approved by the Institutional Review Board of Pusan National University Dental Hospital (PNUDH-2014-027).

Computed tomography (CT) scans were performed using a CBCT scanner (Vatech DCT Pro®; Vatech, Suwon, Korea; scan parameters: 90 kVp, 4.0 mA, and 20- × 19-cm field of view) with a scanning time of 24 seconds. Each patient was scanned in the upright position with maximum intercuspation, from the chin to 180 mm above it. The scanning matrix was 512 × 512 pixels. Subsequently, digital imaging and communications in medicine images were acquired in 1.0-mm-thick cross-sections. The acquired two-dimensional (2D) data were transferred to a personal computer, and each CT image was reconstructed as a 3D image by using a 3D analysis software (Ez3D2009; Vatech).

To establish the standard orientation of the craniofacial structure, the 3D reference planes (horizontal, sagittal, and coronal) were defined as follows (Figure 1B).[17] The XY plane was the horizontal reference plane, defined as the plane passing through the bilateral porion and left orbitale. The YZ plane was the sagittal reference plane, defined as a plane perpendicular to the XY plane and passing through the crista galli and the mid-point between the bilateral porion. The ZX plane was the coronal reference plane, defined as a plane perpendicular to the XY and YZ planes and including the bilateral porion. To determine the middle-third facial landmarks, three horizontal and three sagittal planes were identified as follows. All horizontal planes were parallel to the horizontal reference plane (XY plane). The upper horizontal plane (UH plane) passed the left orbitale; the lower horizontal plane (LH plane) passed the inferior border of the left zygomaticomaxillary suture; and the middle horizontal plane (MH plane) was between the UH and LH planes. All sagittal planes were parallel to the sagittal reference plane (YZ plane). The inner sagittal plane (IS plane) passed the outer rim of the piriform aperture; the middle sagittal plane (MS plane) passed the orbitale; and the outer sagittal plane (OS plane) passed the inferior border of the zygomaticomaxillary suture.

The following horizontal and sagittal plane intersection points were identified for the middle-third facial analysis: S2, superior second point; S3, superior third point; M1, middle first point; M2, middle second point; M3, middle third point; I1, inferior first point; I2, inferior second point; and I3, inferior third point (Figure 1C). MPR images acquired parallel to each horizontal plane were used for the length and angular measurements. The hard-tissue (at intersecting points HS2, HS3, HM1, HM2, HM3, HI1, HI2, and HI3 between the horizontal and sagittal planes, identified in the hard tissues of the middle third of the face) and soft-tissue (at intersecting points SS2, SS3, SM1, SM2, SM3, SI1, SI2, and SI3 between the horizontal and sagittal planes, identified in the soft tissues of the middle third of the face) linear lengths at each horizontal plane were measured perpendicular to the ZX plane (Figure 2). The soft-tissue depth was measured along the sagittal plane at the following points: TS2, TS3, TM1, TM2, TM3, TI1, TI2, and TI3 (TS2 is the soft-tissue depth along the sagittal plane at S2). The differences between the hard-tissue and soft-tissue lengths were then measured (Figure 2).

To evaluate midface convexity, the angles of the maxilla and zygomatic bone with the reference planes were measured. These included the sagittal maxillary angle (SMA) between the UH plane and the tangent line to the anterior maxilla at the MS plane, the sagittal zygomatic angle (SZA) between the UH plane and the tangent line to the anterior border of the zygomatic bone at the OS plane, the transverse zygo-

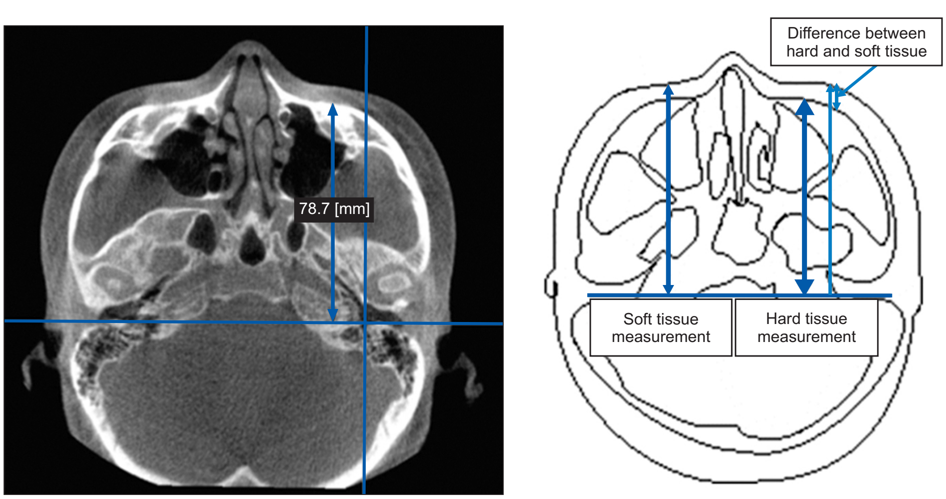

Figure 2. Linear lengths are measured from each hard-tissue (HS2, HS3, HM1, HM2, HM3, HI1, HI2, and HI3) and soft-tissue (SS2, SS3, SM1, SM2, SM3, SI1, SI2, and SI3) landmark point to the ZX plane, which paralleled the horizontal reference planes UH, MH, and LH.

matic angle (TZA) between the inter-orbitale line and the line from the zygomaticomaxillary suture to the zygomaticotemporal suture at the UH plane, the middle transverse maxillary angle between the YZ plane and a line from the HM1 to HM3, and the inferior transverse maxillary angle between the YZ plane and a line from the HI1 to the HI3 (Figure 3). To evaluate the midface surface characteristics, the surface areas of the maxilla and zygomatic bone at each of the horizontal planes were measured. These included the convex zygomatic area (Z-area), the bony contour along the base line between the zygomaticomaxillary suture and the zygomaticotemporal suture at the UH plane; the concave middle maxillary area (M-area) between the anterior maxillary bony contour and a line from the HM1 to HM3; and the concave inferior maxillary area (I-area) between the anterior maxillary bony contour and a line between the HI1 and the HI3 (Figure 4).

Statistical analysis

The data were analyzed using SPSS Statistics for Windows (version 17.0; SPSS, Inc., Chicago, IL, USA). All analyses were performed using the mean values of the right and left sides, except for the comparisons of the right and left sides in each group. The right/left differences in each group were analyzed using a paired *t*-test ($p < 0.05$). The differences between the MD and N groups and between the male and female patients in each group were analyzed using an independent *t*-test ($p < 0.05$).

A weighted kappa coefficient was calculated to evaluate inter- and intra-examiner reliability by using MedCalc software version 12.3.0 (Ostend, Belgium). Intra-examiner reliability was determined by randomly selecting five samples and repeating the digitization (the same examiner was used) 2 weeks later. Inter-examiner reliability was determined by three orthodontists using three random samples. Agreement was defined according to the scale described by Landis and Koch[18] (< 0, no agreement; 0–0.20, slight agreement; 0.21–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.80, substantial agreement; 0.81–1.00, almost perfect agreement).

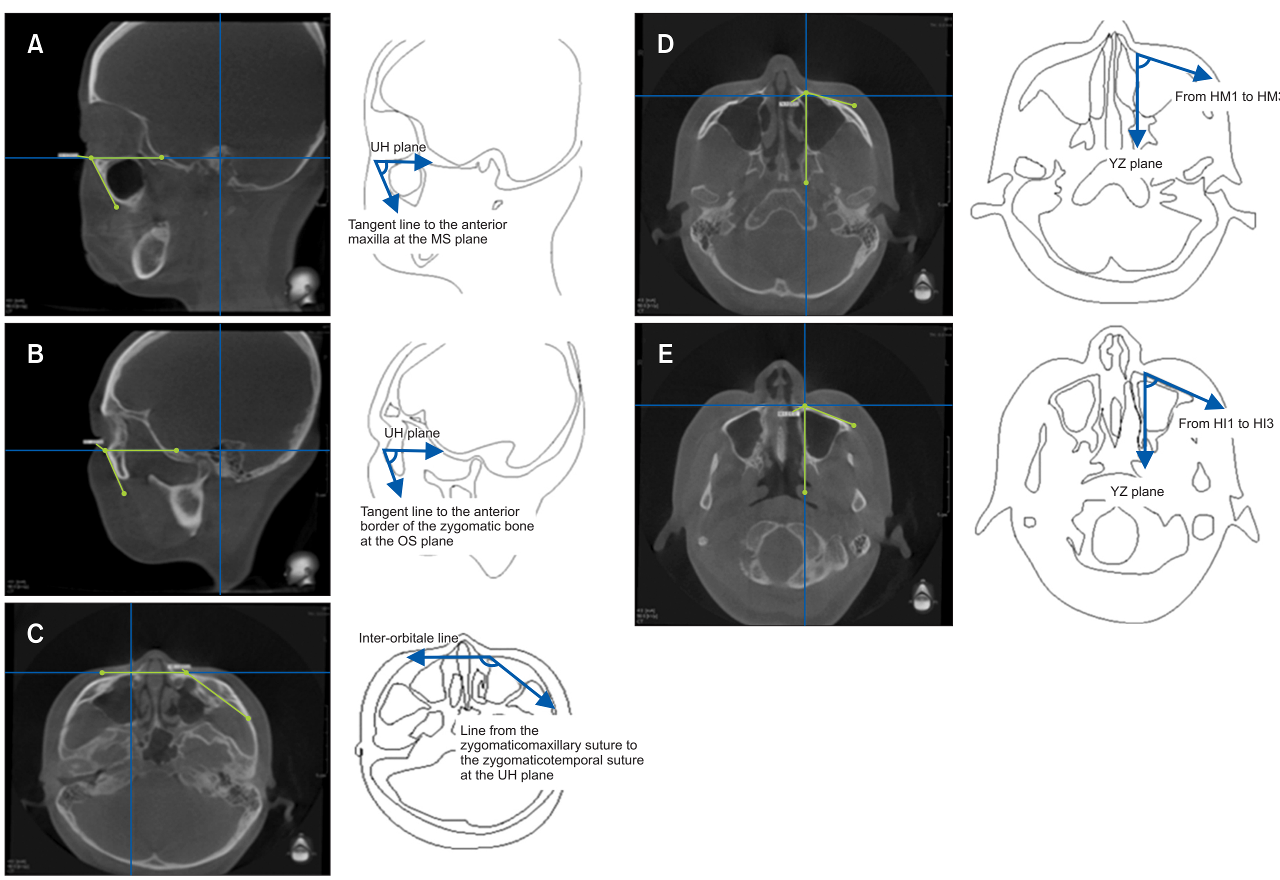

Figure 3. Angular measurements. **A**, Sagittal maxillary angle (SMA). **B**, Sagittal zygomatic angle (SZA). **C**, Transverse zygomatic angle (TZA). **D**, Middle transverse maxillary angle (MTMA). **E**, Inferior transverse maxillary angle (ITMA).

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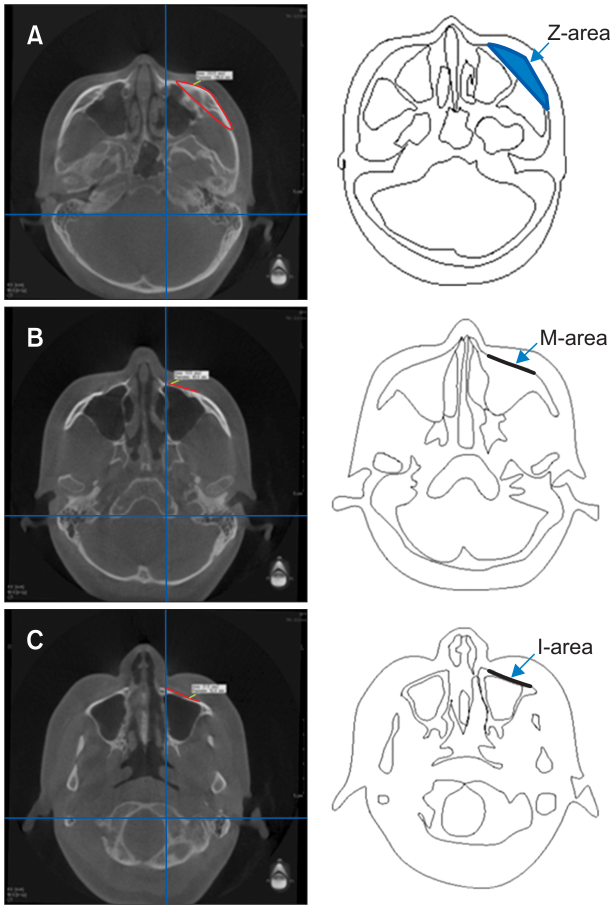

Figure 4. Surface area measurements. **A**, Zygomatic area (Z-area). **B**, Middle maxillary area (M-area). **C**, Inferior maxillary area (I-area).

RESULTS

The intra-examiner reliability analysis showed almost perfect agreement for the midface measurements, with a weighted kappa coefficient of 0.90 (95% confidence interval [CI], 0.86–0.93). The inter-examiner reliability analysis also showed almost perfect agreement for midface measurements, with weighted kappa coefficients ranging from 0.73 (95% CI, 0.66–0.81) to 0.96 (95% CI, 0.95–0.97).

A statistical analysis revealed that the right and left sides of the N group were not significantly different in any measurements except the following: SM1, SMA, and TZA in the male patients, and SZA and TZA in the female patients. Almost none of the measurements in the MD group were significantly different, with the exceptions of HM1, HM2, SM1, and TM3 in the male patients, and SMA and the I-area in the female patients (data not shown).

All measurements were the average values of the right and left sides (Tables 1 and 2). The differences between the N and MD groups for each measurement were analyzed (Table 1). Among the male patients, the lengths of the hard and soft tissues in the N group were longer than those in the MD group. However, among the female patients, only the differences in the HI1, HI2, HI3, SM3, SI2, and SI3 were significant. No difference in soft-tissue thickness was observed among the male or female patients. Significant differences in the SMA and SZA were observed among the female patients, but not among the male patients. The Z-area in the N group was larger than that in the MD group, and the I-area in the N group was smaller than that in the MD group for both male and female patients. The only significant difference was observed in the M-area of the male patients.

All of the hard- and soft-tissue measurements in the N group showed significant differences between the male and female patients (Table 2). However, in the MD group, only the SI1 showed a significant difference. With regard to soft-tissue thickness, angular, and area measurements, the TI1 and TZA in the N group and the M-area in the MD group showed significant differences.

DISCUSSION

The midface is defined as the region between the eyebrows and subnasale, and includes the zygoma and maxilla.[10] Despite its importance in facial geometry, the number of studies of sagittal and frontal measurements of the midface is insufficient. Few studies have investigated the sagittal measurements using 2D plain radiography.[4-9] Moreover, there have been no previous studies that have used 3D measurements. The midface, consisting of the zygoma and anterior and lateral walls of the maxilla, requires measurements of each of these areas, which is difficult. In the present study, we attempted to determine the 3D characteristics of the midface by using CBCT-derived MPR images.

Chien et al.[19] traced changes by age and defined three angles in the lateral aspect and one area in the frontal aspect by using 3D-CBCT-reconstructed images. They could not find a relationship between any of the angular measurements and midface characteristics. Another study by Nocini et al.[13] used three vertical and five horizontal lines to examine patients scheduled to undergo malar implant surgery, but included no objective midface measurements. In addition, both studies focused on hard tissues; they analyzed the soft tissues only in some patients. Hwang et al.[20] studied the relationships between hard- and soft-tissue facial asymmetry by using 3D-CT and found differences in six mandibular measurements: chin deviation, frontal ramal inclination, frontal corpus inclination, lip cheilion height, maxillary height, and occlusal plane canting.

Table 1. Comparison between the midface deficiency (MD) and normal groups

Variable	Male				Female			
	MD	Normal	Avg. Diff.	*p*-value	MD	Normal	Avg. Diff.	*p*-value
Hard tissue measurement (mm)								
HS2	78.41 ± 4.83	83.50 ± 3.41	5.09	0.01*	75.14 ± 3.69	77.04 ± 2.14	1.90	0.18
HS3	74.13 ± 4.88	79.18 ± 3.93	5.05	0.02*	70.45 ± 2.94	72.52 ± 2.29	2.07	0.10
HM1	80.38 ± 4.83	85.11 ± 4.16	4.73	0.03*	76.94 ± 3.26	79.86 ± 3.25	2.92	0.06
HM2	75.87 ± 5.08	81.37 ± 3.87	5.50	0.01*	72.94 ± 2.58	75.55 ± 3.48	2.61	0.07
HM3	71.78 ± 5.18	76.75 ± 3.39	4.97	0.02*	68.03 ± 2.58	70.18 ± 2.13	2.15	0.06
HI1	77.19 ± 5.39	82.83 ± 4.66	5.64	0.02*	73.93 ± 3.30	77.78 ± 3.19	3.85	0.02*
HI2	71.51 ± 5.82	77.76 ± 4.23	6.25	0.01*	68.57 ± 3.26	72.22 ± 2.98	3.65	0.02*
HI3	67.56 ± 5.38	72.68 ± 3.86	5.12	0.03*	63.75 ± 2.47	67.27 ± 2.60	3.52	0.01*
Soft tissue measurement (mm)								
SS2	86.17 ± 5.06	91.24 ± 3.96	5.07	0.02*	82.16 ± 3.96	84.56 ± 2.23	2.40	0.11
SS3	82.30 ± 5.34	86.95 ± 4.60	4.65	0.05	78.83 ± 3.53	80.64 ± 1.39	1.81	0.15
SM1	90.60 ± 5.91	95.45 ± 4.75	4.85	0.06	86.30 ± 3.95	89.48 ± 3.01	3.18	0.06
SM2	86.95 ± 6.30	92.74 ± 4.68	5.79	0.03*	83.71 ± 3.93	86.59 ± 2.39	2.88	0.06
SM3	83.87 ± 6.14	89.02 ± 4.71	5.15	0.05	80.82 ± 3.01	83.36 ± 1.37	2.54	0.03*
SI1	90.00 ± 5.53	95.07 ± 4.71	5.07	0.04*	85.37 ± 4.17	88.50 ± 3.71	3.13	0.09
SI2	88.32 ± 6.90	94.25 ± 5.16	5.93	0.04*	84.81 ± 4.08	88.22 ± 2.65	3.41	0.04*
SI3	83.98 ± 7.07	89.18 ± 5.17	5.20	0.08	80.72 ± 2.84	83.68 ± 1.73	2.96	0.01*
Soft tissue thickness measurement (mm)								
TS2	7.80 ± 1.11	7.95 ± 1.84	0.15	0.83	7.05 ± 0.76	7.56 ± 1.06	0.51	0.23
TS3	8.18 ± 1.30	7.80 ± 1.16	0.38	0.50	8.40 ± 1.19	8.17 ± 1.47	0.23	0.71
TM1	10.25 ± 1.57	10.38 ± 1.49	0.13	0.85	9.39 ± 1.47	9.63 ± 1.26	0.24	0.70
TM2	11.10 ± 1.82	11.42 ± 1.81	0.32	0.70	10.79 ± 2.00	11.06 ± 1.66	0.00	0.75
TM3	12.10 ± 1.69	12.29 ± 1.81	0.19	0.81	12.81 ± 1.43	13.22 ± 1.81	0.41	0.58
TI1	12.83 ± 1.37	12.27 ± 1.45	0.56	0.39	11.47 ± 1.87	10.74 ± 1.29	0.73	0.32
TI2	16.86 ± 2.50	16.52 ± 2.52	0.34	0.76	16.27 ± 1.61	16.03 ± 1.04	0.24	0.70
TI3	16.45 ± 2.39	16.53 ± 2.55	0.08	0.94	17.00 ± 1.78	16.43 ± 2.14	0.00	0.53
Angular measurement (°)								
SMA	62.99 ± 5.47	67.26 ± 6.02	4.27	0.11	62.81 ± 3.40	67.70 ± 3.83	4.89	0.01*
SZA	64.84 ± 4.01	68.65 ± 5.14	3.81	0.08	65.68 ± 5.12	72.22 ± 4.44	6.54	0.01*
ITMA	70.71 ± 4.10	66.93 ± 5.07	3.78	0.08	70.49 ± 3.31	67.26 ± 4.47	3.23	0.08
MTMA	74.48 ± 3.40	77.78 ± 5.12	3.30	0.11	73.21 ± 2.21	74.29 ± 3.67	1.08	0.44
TZA	137.45 ± 6.78	135.90 ± 3.50	1.55	0.53	137.90 ± 1.70	138.95 ± 2.36	1.05	0.27
Surface area measurement (mm^2)								
Z-area	212.31 ± 79.50	313.47 ± 93.30	101.16	0.02*	225.52 ± 61.79	286.62 ± 42.96	61.10	0.02*
I-area	42.50 ± 34.41	8.89 ± 5.61	33.61	0.01*	27.94 ± 11.21	8.42 ± 4.67	19.52	0.00*
M-area	24.90 ± 11.39	9.97 ± 12.58	14.93	0.01*	11.87 ± 8.84	7.93 ± 5.01	3.94	0.24

Values are presented as mean ± standard deviation.
All measurements were the average values of the right and left sides.
Avg. Diff., Average difference; calculated differences between the MD and normal groups.
*$p < 0.05$.
Refer to Figures 1–4 for the description of each measurement.

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Table 2. Comparison between male and female patients

Variable	Male				Female			
	MD	Normal	Avg. Diff.	*p*-value	MD	Normal	Avg. Diff.	*p*-value
Hard tissue measurement (mm)								
HS2	83.50 ± 3.41	77.04 ± 2.14	6.46	0.00*	78.41 ± 4.83	75.14 ± 3.69	3.27	0.11
HS3	79.18 ± 3.93	72.52 ± 2.29	6.66	0.00*	74.13 ± 4.88	70.45 ± 2.94	3.68	0.06
HM1	85.11 ± 4.16	79.86 ± 3.25	5.25	0.01*	80.38 ± 4.83	76.94 ± 3.26	3.44	0.08
HM2	81.37 ± 3.87	75.55 ± 3.48	5.82	0.00*	75.87 ± 5.08	72.94 ± 2.58	2.93	0.12
HM3	76.75 ± 3.39	70.18 ± 2.13	6.57	0.00*	71.78 ± 5.18	68.03 ± 2.58	3.75	0.06
HI1	82.83 ± 4.66	77.78 ± 3.19	5.05	0.01*	77.19 ± 5.39	73.93 ± 3.30	3.26	0.12
HI2	77.76 ± 4.23	72.22 ± 2.98	5.54	0.00*	71.51 ± 5.82	68.57 ± 3.26	2.94	0.18
HI3	72.68 ± 3.86	67.27 ± 2.60	5.41	0.00*	67.56 ± 5.38	63.75 ± 2.47	3.81	0.06
Soft tissue measurement (mm)								
SS2	91.24 ± 3.96	84.56 ± 2.23	6.68	0.00*	86.17 ± 5.06	82.16 ± 3.96	4.01	0.06
SS3	86.95 ± 4.60	80.64 ± 1.39	6.31	0.00*	82.30 ± 5.34	78.83 ± 3.53	3.47	0.10
SM1	95.45 ± 4.75	89.48 ± 3.01	5.97	0.00*	90.60 ± 5.91	86.30 ± 3.95	4.30	0.07
SM2	92.74 ± 4.68	86.59 ± 2.39	6.15	0.00*	86.95 ± 6.30	83.71 ± 3.93	3.24	0.18
SM3	89.02 ± 4.71	83.36 ± 1.37	5.66	0.00*	83.87 ± 6.14	80.82 ± 3.01	3.05	0.18
SI1	95.07 ± 4.71	88.50 ± 3.71	6.57	0.00*	90.00 ± 5.53	85.37 ± 4.17	4.63	0.05
SI2	94.25 ± 5.16	88.22 ± 2.65	6.03	0.01*	88.32 ± 6.90	84.81 ± 4.08	3.51	0.18
SI3	89.18 ± 5.17	83.68 ± 1.73	5.50	0.01*	83.98 ± 7.07	80.72 ± 2.84	3.26	0.20
Soft tissue thickness measurement (mm)								
TS2	7.95 ± 1.84	7.56 ± 1.06	0.39	0.57	7.80 ± 1.11	7.05 ± 0.76	0.75	0.10
TS3	7.80 ± 1.16	8.17 ± 1.47	0.37	0.54	8.18 ± 1.30	8.40 ± 1.19	0.22	0.60
TM1	10.38 ± 1.49	9.63 ± 1.26	0.75	0.24	10.25 ± 1.57	9.39 ± 1.47	0.86	0.22
TM2	11.42 ± 1.81	11.06 ± 1.66	0.36	0.65	11.10 ± 1.82	10.79 ± 2.00	0.31	0.72
TM3	12.29 ± 1.81	13.22 ± 1.81	0.93	0.27	12.10 ± 1.69	12.81 ± 1.43	0.71	0.32
TI1	12.27 ± 1.45	10.74 ± 1.29	1.53	0.02*	12.83 ± 1.37	11.47 ± 1.87	1.36	0.08
TI2	16.52 ± 2.52	16.03 ± 1.04	0.49	0.58	16.86 ± 2.50	16.27 ± 1.61	0.59	0.54
TI3	16.53 ± 2.55	16.43 ± 2.14	0.10	0.93	16.45 ± 2.39	17.00 ± 1.78	0.55	0.57
Angular measurement (°)								
SMA	67.26 ± 6.02	67.70 ± 3.83	0.44	0.85	62.99 ± 5.47	62.81 ± 3.40	0.18	0.93
SZA	68.65 ± 5.14	72.22 ± 4.44	3.57	0.11	64.84 ± 4.01	65.68 ± 5.12	0.84	0.69
ITMA	66.93 ± 5.07	67.26 ± 4.47	0.33	0.88	70.71 ± 4.10	70.49 ± 3.31	0.22	0.90
MTMA	77.78 ± 5.12	74.29 ± 3.67	3.49	0.10	74.48 ± 3.40	73.21 ± 2.21	1.27	0.34
TZA	135.90 ± 3.50	138.95 ± 2.36	3.05	0.04*	137.45 ± 6.78	137.90 ± 1.70	0.45	0.84
Surface area measurement (mm^2)								
Z-area	313.47 ± 93.30	286.62 ± 42.96	26.85	0.42	212.31 ± 79.50	225.52 ± 61.79	13.21	0.68
I-area	8.89 ± 5.61	8.42 ± 4.67	0.47	0.84	42.50 ± 34.41	27.94 ± 11.21	14.56	0.22
M-area	9.97 ± 12.58	7.93 ± 5.01	2.04	0.64	24.90 ± 11.39	11.87 ± 8.84	13.03	0.01*

Values are presented as mean ± standard deviation.
All measurements were the average values of the right and left sides.
Avg. Diff., Average difference; calculated differences between the midface deficiency (MD) and normal groups.
*$p < 0.05$.
Refer to Figures 1–4 for the description of each measurement.

Although several studies have isolated characteristics of the midface and facial asymmetry by using 3D-CT, no 3D-CBCT study to date has compared the hard- and soft-tissue characteristics of the midface. The present study aimed to determine the midface characteristics of patients with skeletal class III malocclusion by focusing on hard- and soft-tissue relationships and angular and surface measurements using CBCT-derived MPR images.

The mean differences between the right and left sides of the midface in each group are not listed. Almost none of the mean values showed a significant difference, as the patients with marked facial asymmetry (such as those having a mandibular menton point deviation > 4 mm) were excluded from the study. The mean differences between the MD and N groups are listed in Table 1. The lengths of the hard and soft tissues in the N group were longer than those in the MD group. For the female patients, only the differences in hard tissue (HI1, HI2, and HI3) and soft tissue (SM3, SI2, and SI3), as measured from the lower part of the midface, were significant.

All facial regions of the male patients in the MD group were located posterior to those of the male patients in the N group. Among the female patients in the MD group, only the inferior section of the midface was located relative to that of the female patients in the N group. Similarly, Ferrario et al.[21] reported that the facial volumes of women with skeletal class III malocclusion were smaller than those of normal women, whereas the lower lips and noses were larger. These findings of the midface characteristics of Korean women with skeletal class III malocclusion were consistent with those of previous reports on Europeans. Ferrario et al.[22] showed that in orthognathic surgery of the midface, retropositioning of the lower third of the face allows relative advancement of the middle third facial area. Soncul and Bamber[23] conducted an optical scanner study and found that the facial areas that were more modified after bimaxillary surgeries were located roughly around the subnasale or on the upper lip. Other studies on the surgical changes to the midface of Asian subjects have reported similar findings.[24,25]

As mentioned above, the midface characteristics of male and female candidates for orthognathic surgery were considered in the present study, and no difference was observed in the soft-tissue thicknesses between the sexes. Cho et al.[26] reported differences in soft-tissue thickness in the bilateral region of the asymmetric mandible, clearly reflecting skeletal-morphological variances. Kwon et al.[27] asserted that bilateral differences in muscle volume in patients with mandibular prognathism would reflect differences in the spatial anatomy of skeletal structures and, thus, could not predict mandibular skeletal asymmetry. However, in the present study, no significant differences were observed even when skeletal-morphological differences were present, possibly because we included symmetric patients. Indeed, the soft tissue covering the midface is less affected by facial muscle activity than is the soft tissue covering the mandible. If facial muscle morphology is affected by muscular activity, the thickness of the soft tissue covering the mandible could vary, but not in the midface region.

A slight increase in soft-tissue thickness was noted in the outer points than in the inner points, but this was reversed for tissue length. Moreover, the soft-tissue thickness at an inferior point was thicker than that at a superior point. However, the differences in soft-tissue thicknesses within the MD and N groups were not significant. Vertical soft-tissue morphologies are affected by soft-tissue thickness, but the differences were too small to be decisive. Thus, soft-tissue thickness might be an insufficient indicator of MD. Therefore, we suggest using the differences between the inferior portions of the hard- and soft-tissue lengths as alternative means of MD characterization.

A comparison of the MD and N groups revealed a significant difference in the SMA and SZA among the female patients, but not among the male patients. This suggests that MD characterization using the angular measurements we have chosen may not be suitable. Therefore, careful selection of the measurements for representing 3D facial morphology in the MPR views is necessary.

In the N group, the Z-area representing the prominence of the zygoma was significantly larger than that in the MD group. In contrast, the TZA, representing the core line of the zygoma in the horizontal plane, did not show such a significant intergroup difference. This suggests that the zygomatic body shape influences MD but the core line angle does not. Nonetheless, younger Asian female patients have a negative perception of angular cheekbones and a square facial shape. Hence, esthetic surgery to alter such features in favor of a softer, gentler facial contour has become a common request.[28] These types of ethnically varying esthetic guidelines regarding corrective surgery for MD must also be considered.[24,25]

The I-area, representing the characteristics of the LH plane, was larger in the MD group than in the N group. Accordingly, the anterior midface region was more concave in the MD group than in the N group. Additionally, the M-area showed significant differences among the male patients, but not among the female patients. Thus, the MH plane cannot properly represent MD characteristics because the change does not have sufficient statistical power. The mean differences between the male and female patients are listed in Table 2. All of the hard- and soft-tissue measurements

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for the N group revealed significant sex differences, but in the MD group, only the SI1 showed a significant difference. With regard to soft-tissue thickness, in the angular and area measurements, the TI1 and TZA in the N group and the M-area in the MD group revealed significant differences. Almost all of the measurements comparing the male and female patients in the N group were significant, but a similar trend was not observed in the MD group. This implies that in the N group, unlike in the MD group, the male patients were on average significantly larger. Neither soft-tissue thickness, angle, nor area showed any significant differences.

In this study, we used CBCT-derived MPR images instead of 3D-reconstructed images. The former methodology offers advantages such as increased accuracy, but is difficult to perform and is less intuitive. Therefore, future studies should combine MPR images with 3D-reconstructed images for more effective analyses of the midface region.

CONCLUSION

This study demonstrated the difference between MD and normal face by using MPR images derived from CBCT. Male patients in the MD group had more flattened faces than did those in the N group, but female patients in the MD group showed a concave form of the lower section of the zygoma, which tended to have a more severe MD. This indicates that orthognathic surgery to improve a skeletal discrepancy requires different approaches for male and female patients.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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